Knight: Chapter 16

A Macroscopic Description of Matter

(*Ideal-Gas Processes*)

Quiz Question 1

The temperature of a rigid (constant-volume), sealed container of gas *increases* from 100°C to 200°C.

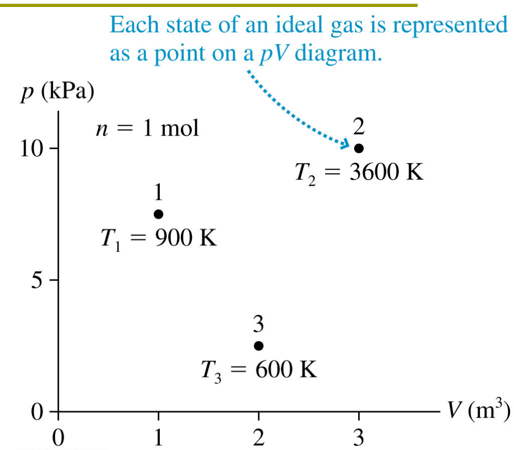
The gas pressure *increases* by a factor of

$\frac{473K}{373K} = 1.3$

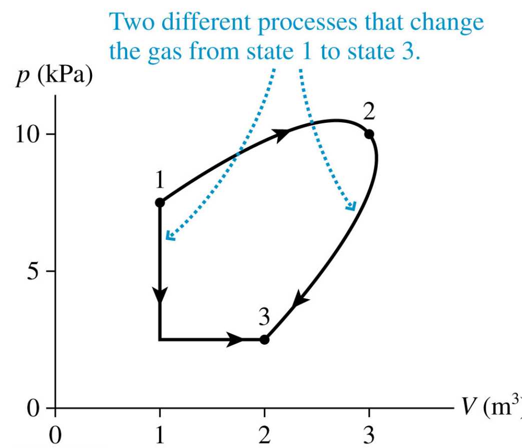
1. 2.
2. 1.3.
3. 1 (the pressure doesn't change).
4. 0.8.
5. 0.5.

Ideal-Gas Processes…

- can be represented on a graph of *pressure vs volume*
  (a.k.a. *pV diagram)*
- knowing p & V for a *given n*, we can find the temp T using the ideal-gas law.



- ∞'ly many ways to change gas from state 1 to state 3.
  - Here are two different 'trajectories' on the pV diagram.



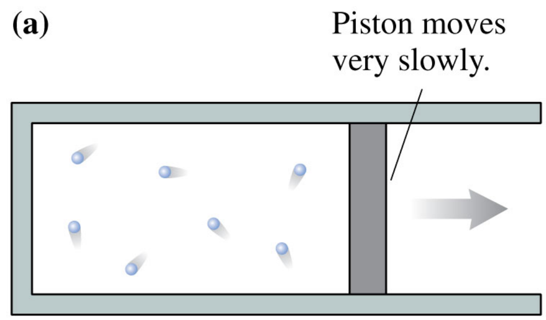
Ideal-Gas Processes…

Quasi-static process:

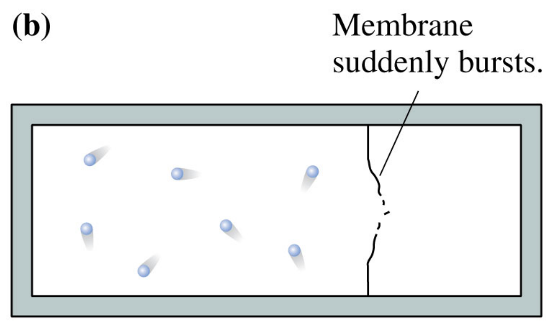
- process that is essentially in *thermal equilibrium* at all times.
  - (a) If you *slowly pull* a piston out, you can reverse the process by *slowly pushing* the piston in.
  - (b) is NOT quasi-static & cannot be represented on a pV diagram.

Notice:

This textbook will *always* assume that processes are *quasi-static.*



Quasi-static process

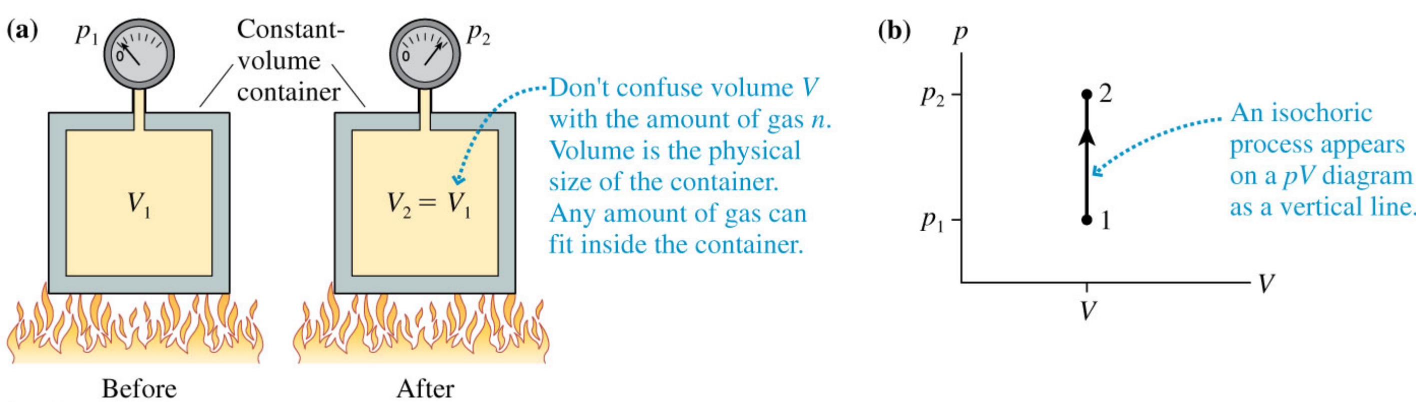


Irreversible process

Constant-Volume Process…

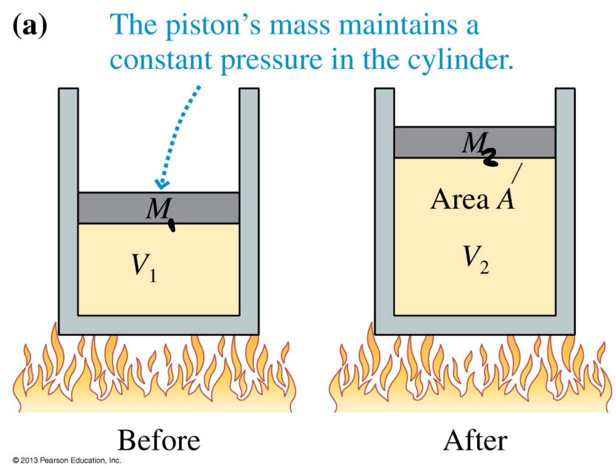
a.k.a. *isochoric process* (volume doesn't change)

- the gas is in a *closed, rigid container*.
- Warming the gas with a flame will *raise its pressure* w/out changing its volume.
- *Vertical* line on *pV* diagram



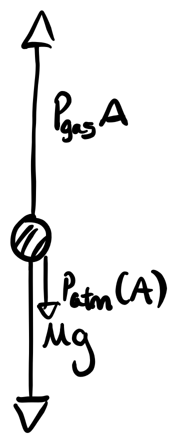
Constant-Pressure Process…

a.k.a. *isobaric process* Constant pressure



- The pressure of the gas is:

$$P = \frac{F}{A} \; : \; F = PA$$



$$P_{gas}A = P_{atm}A + mg$$

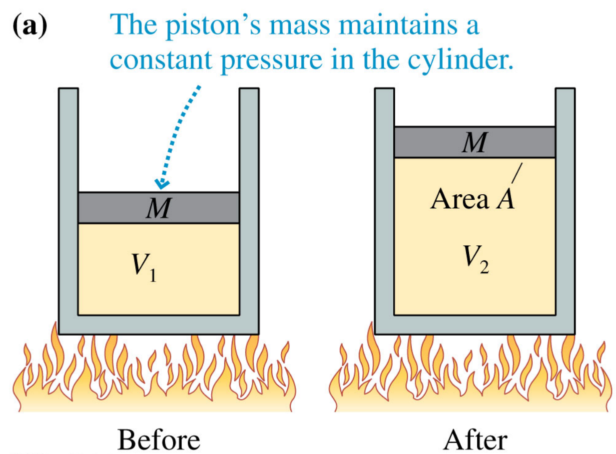
$$P_{gas} = P_{atm} + \frac{mg}{A}$$

Constant-Pressure Process…

a.k.a. *isobaric process*

- The pressure of the gas is:

$$p_{gas} = p_{atm} + \frac{Mg}{A}$$

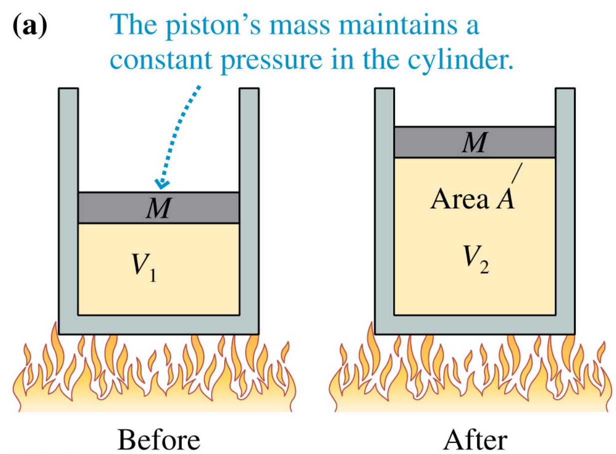


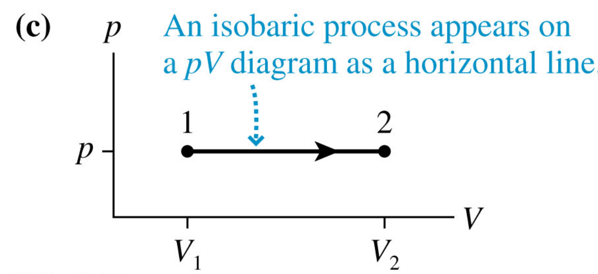
- The pressure is *independent* of the *temperature* of the gas or the height of the piston, so it stays *constant* as long as *M* is unchanged.

Constant-Pressure Process…

a.k.a. *isobaric process*

- Warming the gas with a flame will *raise its volume* w/out changing its pressure.
- *Horizontal* line on *pV* diagram





$$PV = nRT$$

$$T = \frac{PV}{nR}$$

$$P = \frac{nRT}{V}$$

Quiz Question 2

A cylinder of gas has a frictionless but tightly sealed piston of mass *M*. The gas temperature is increased from an initial 27°C to a final 127°C.

What is the final-to-initial volume ratio V_f/V_i?

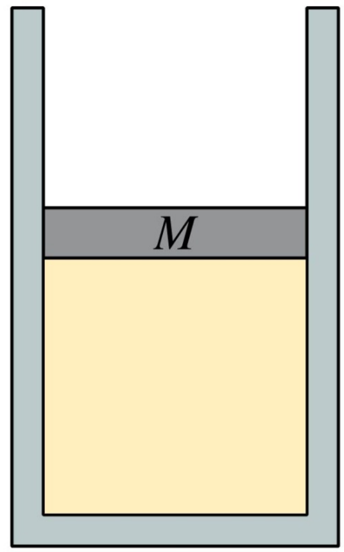
$PV = nRT$ 300K 400K

$P = \frac{nRT}{V}$

1. 1.50
2. 1.33
3. 1.25
4. 1.00
5. Not enough information to tell.

$\frac{nRT_1}{V_1} = \frac{nRT_2}{V_2}$

$\frac{V_2}{V_1} = \frac{T_2}{T_1}$ $\frac{V_2}{V_1} = \frac{4}{3}$



Constant-Temperature Process…

a.k.a. *isothermal process* Constant temperature

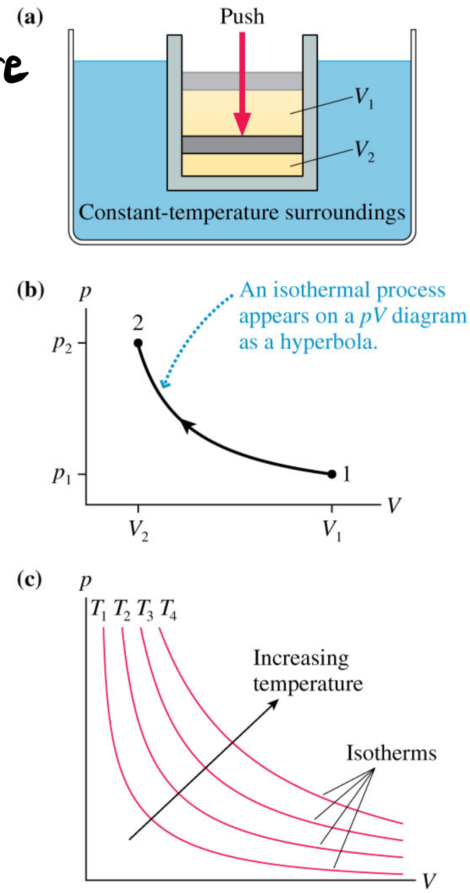
- Consider a piston being pushed down to *compress* a gas…
- Heat is transferred through the walls of the cylinder to keep *T* fixed, so that:

$$PV = nRT$$

$$T = \frac{PV}{nR}$$

$$p = \frac{nRT}{V}$$

$$p = \frac{\text{constant}}{V}$$



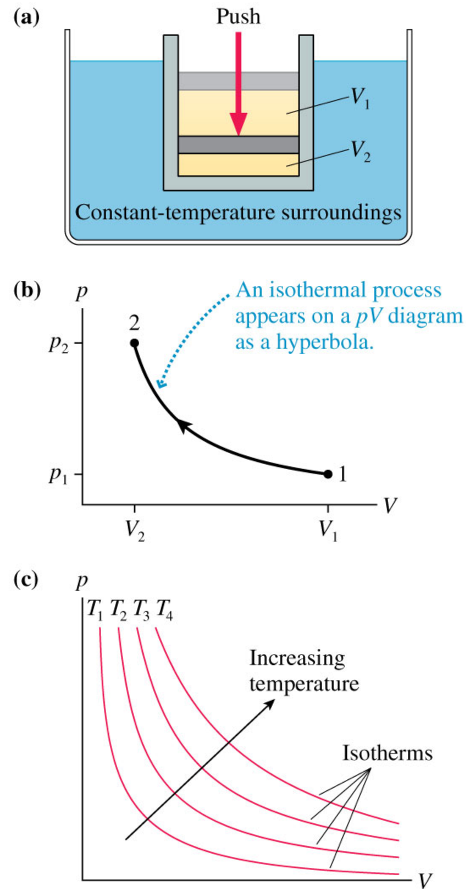
Constant-Temperature Process…

a.k.a. *isothermal process*

- Consider a piston being pushed down to *compress* a gas…
- Heat is transferred through the walls of the cylinder to keep T fixed, so that:

$$\boxed{p = \frac{\text{const}}{V}}$$

- The graph of p vs V for an *isotherm* is a *hyperbola*.



Quiz Question 3

A gas follows the process shown.

What is the final-to-initial temperature ratio T_f / T_i?

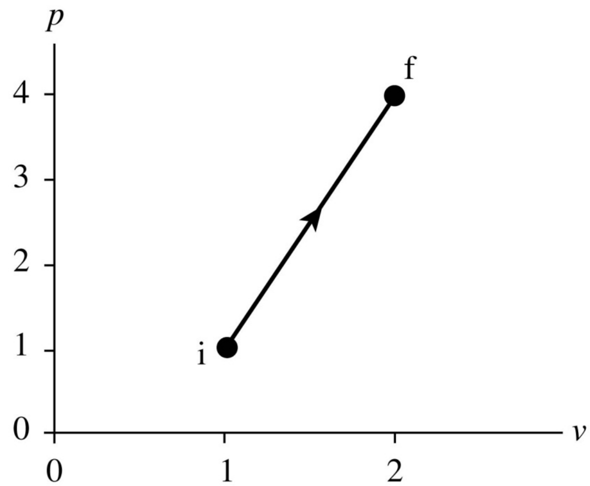
$pV = nRT$

$T = \frac{pV}{nR}$

$(1)(1) = 1$

$(2)(4) = 8$

$8 : 1$



1. 2
2. 4
3. 8
4. 16
5. Not enough information to tell.

i.e.16.9: Compressing air in the lungs

An ocean snorkeler takes a deep breath at the surface, filling his lungs with 4.0L of air. He then descends to a depth of 5.0m.

At this depth, what is the volume of air in the snorkeler's lungs?

$4.0L = 4.0\times10^{-3} m^3$

$P_1V_1 = nRT$ $\quad$ $P_2V_2 = nRT$

$\frac{P_1V_1}{nR} = T$ $\quad$ $T = \frac{P_2V_2}{nR}$

$P_1 = 1.01\times10^5\ N/m^2$

$V_1 = 4.0\times10^{-3} m^3$

$P_2 = P_1 + \rho g h$

$\frac{P_1V_1}{nR} = \frac{P_2V_2}{nR}$

$P_1V_1 = P_2V_2$

$V_2 = \frac{P_1V_1}{P_2}$

$P_2 = 1.01\times10^5 N/m^2 + (1030\ \frac{kg}{m^3})(9.8 m/s^2)(5m)$

$P_2 = 1.5\times10^5\ N/m^2$

$V_2 = \frac{(1.01\times10^5\ N/m^2)(4.0\times10^{-3} kg/m^3)}{(1.5\times10^5 N/m^2)}$

$V_2 = 2.7\times10^{-3} m^3 = 2.7L$

$V_2 = 2.7L$

i.e.16.10:
A multi-step process

A gas at 2.0 atm pressure and a temperature of 200° C is first expanded isothermally until its volume has doubled. It then undergoes an isobaric compression until it returns to its original volume.

First show this process on a *pV* diagram. Then find the final temperature and pressure.

$T = \frac{PV}{nR}$

$P = \frac{nRT}{V}$

$P_1 = 2.02 \times 10^5\ N/m^2$

$T_1 = 473\ K$

$V_1 =$

$V_2 = 2V_1$

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$P_1 V_1 = P_2 V_2$$

$$P_1 V_1 = P_2 2V_1$$

$$P_2 = \frac{1}{2}$$

i.e.16.10:
A multi-step process

A gas at 2.0 atm pressure and a temperature of 200° C is first expanded isothermally until its volume has doubled. It then undergoes an isobaric compression until it returns to its original volume.

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